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Simulation and Optimization of Microcantilever Biosensors

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Biosensors, which convert biology excitation into measurable signals, are gaining interests across different research areas including biology, chemistry, electrical & electronic engineering, and mechanical engineering. A typical biosensor usually consists of three parts: a biological recognition element, a transducer, and a detector element [1]. As one of the most common type of biosensors, microcantilever biosensor has been used to detect prostate cancer by identifying prostate-specific antigen [2], humidity [3], herbicide [4], metal ion [5], temperature and radiation [6] by applying specific biological recognition element on the cantilever surface. The development of microcantilever biosensors has been summarized by Hwang et al. [7]. When the biological recognition element was stimulated by biomolecular surface stress of cantilever, it led to deflection. The relationship between the stress and deflection can be described by Stoney equation for the cantilever with a rectangular cross section [8]. Since the static loading induced deflections are usually in the order of tens to hundreds of one nanometer, detection of such small deflection is a challenge. Dynamic mode of microcantilever has been designed to detect small variations in mass load resulting from adsorption and desorption of molecules [9]. The resonance frequencies of cantilever vary with the additional analyte. Take the recent invented nanocantilever sensors for example, the sensitivity could achieve1 attogram, i.e., 10^{-18} g.

The sensitivity of micro- and nano-cantilever biosensors depends on the measurement techniques and the cantilever design including material, shape, profile, dimension, etc. For example, a highly flexible cantilever will lead to relatively larger deflection for effective detection. However, this is at the expense of an increase in noise level, which will affect the accuracy of resonant frequency of cantilevers. Thus, optimal design of cantilevers to obtain the high deflection abilities and sufficient frequency characteristics is in immediate need [10]. Ansari et al. [11] recently proposed a stepped cantilever with a u-shaped piezoresistor and enhanced the design through finite element modeling.

Finite element method has been increasingly used to investigate the performance of various biosensor designs by evaluating the influence of cantilever parameters on its static deflection and natural frequency. The deflection induced by the surface stress is generally simulated by action of an equivalent in-plane tensile force on the surface of the cantilever. Being a major source of noise, the thermal drifting should be considered. In addition, the spatial arrangement of the cantilevers array could also be a source of noise. Studies in this aspect remain largely unexplored. Furthermore, biosensors are usually operated in liquid environment. Flow excitation may considerably influence dynamic properties of cantilevers. Fluid damping is speculated to cause the discrepancy between theoretical and experimental dynamic analysis [12]. The computational modeling of microcantilever biosensors operating in liquid environment is also lacking.

The publication of studies concerning simulation and optimization of microcantilever biosensors in an open access journal such as Journal of Biosensors and Bioelectronics is essential to gain insights on the potential of these sensors as well as to advance their design. The computational modeling of coated microcantilever or nanocantilever biosensors have not yet been fully exploited, which may allow the biologist to probe the living cells or molecule within specific physiological or pathological settings. Readers will mostly appreciate the broader applications of simulation and optimization methodology to the area of biomedical or drug discovery.

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